REFUGE ALTERNATIVE HEAT MITIGATION USING LIQUID AIR TECHNOLOGY

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CHEMBIO SHELTER, INC.

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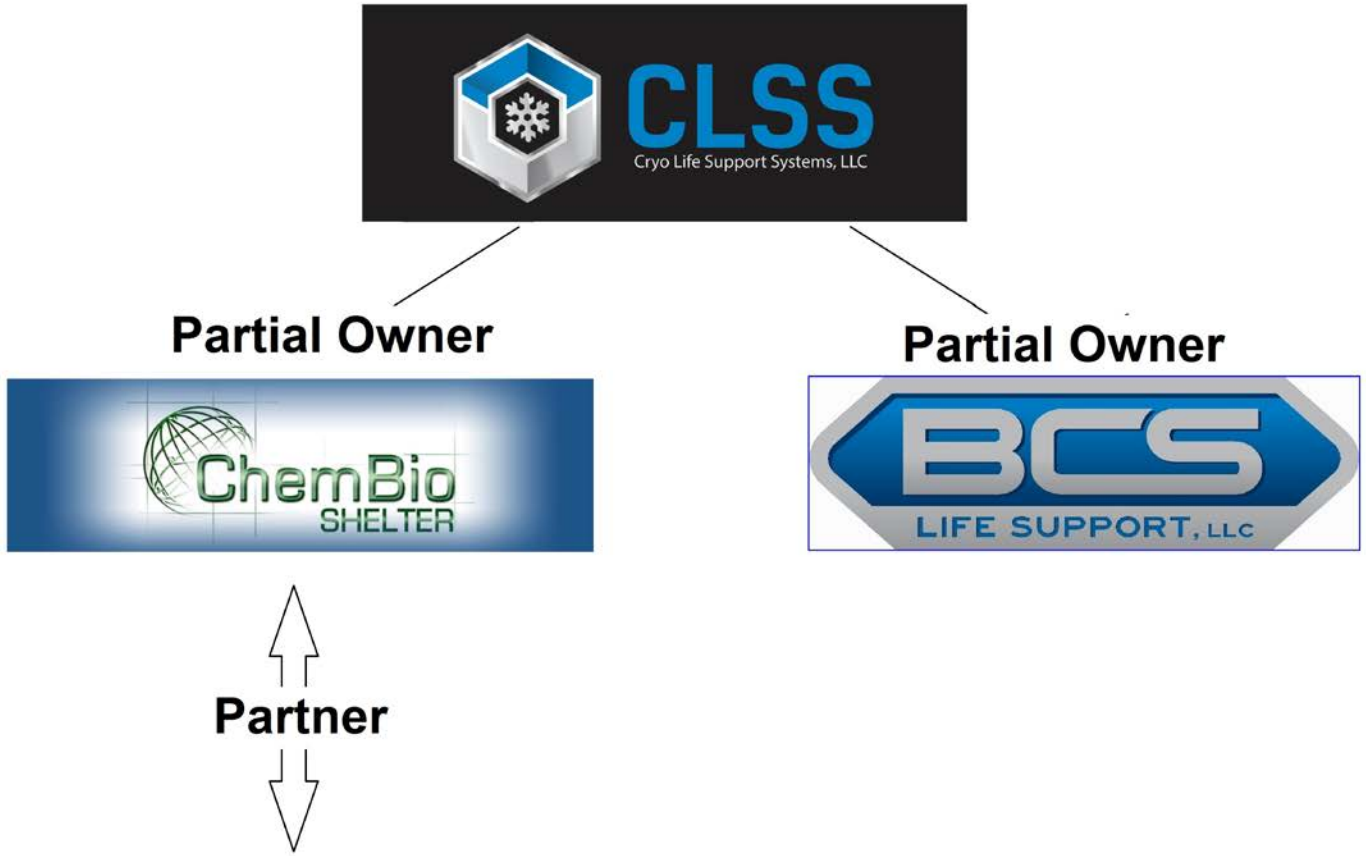
Company Relationships



By the end of 2018, must prove all RAs meet the 95°F apparent temperature limit.

ChemBio will offer 4 solutions:

1. **Cryogenic Liquid Air Supply System.**
2. **Borehole Blower with Air Handling Unit.**
3. **Intrinsically Safe Electric Air Conditioner.**
4. **Derating.**

What is liquid air?

Air that has been liquidized by compression and cooling to extremely low temperatures.

Properties of Liquid Air

Boiling Point	-318 deg F
Oxygen	20.9% (Boiling Point -297.3 deg F)
Nitrogen	78.1% (Boiling Point -320.4 deg F)
Argon	0.9%
Carbon Dioxide	0.038%
Heat of Vap(orization	88.38 BTU/lb
Specific Heat	0.2427 BTU/lb deg F
Density	1.9268 lb/liter

Liquid Air Testing to maintain Apparent Temperature below 95 deg F.

Completed

November 2014, at Bruceton, 23 Man Inflatable, 1,100 Liters Liquid Air.
October, 2015, at Bruceton, 30 Man BIP, 1250 Liters Liquid Air.

In Progress

34 man inflatable baseline test. No cooling.
34 man inflatable with 1750 Liters Liquid Air cooling.
34 man inflatable, mine ambient at 75 deg F, with 1750 Liters Liquid Air cooling.
34 man BIP, BIP area of the mine at 75 deg F, with 1750 Liters Liquid Air cooling.

MODEL CLSS1500 CRYO LIFE SUPPORT SYSTEM

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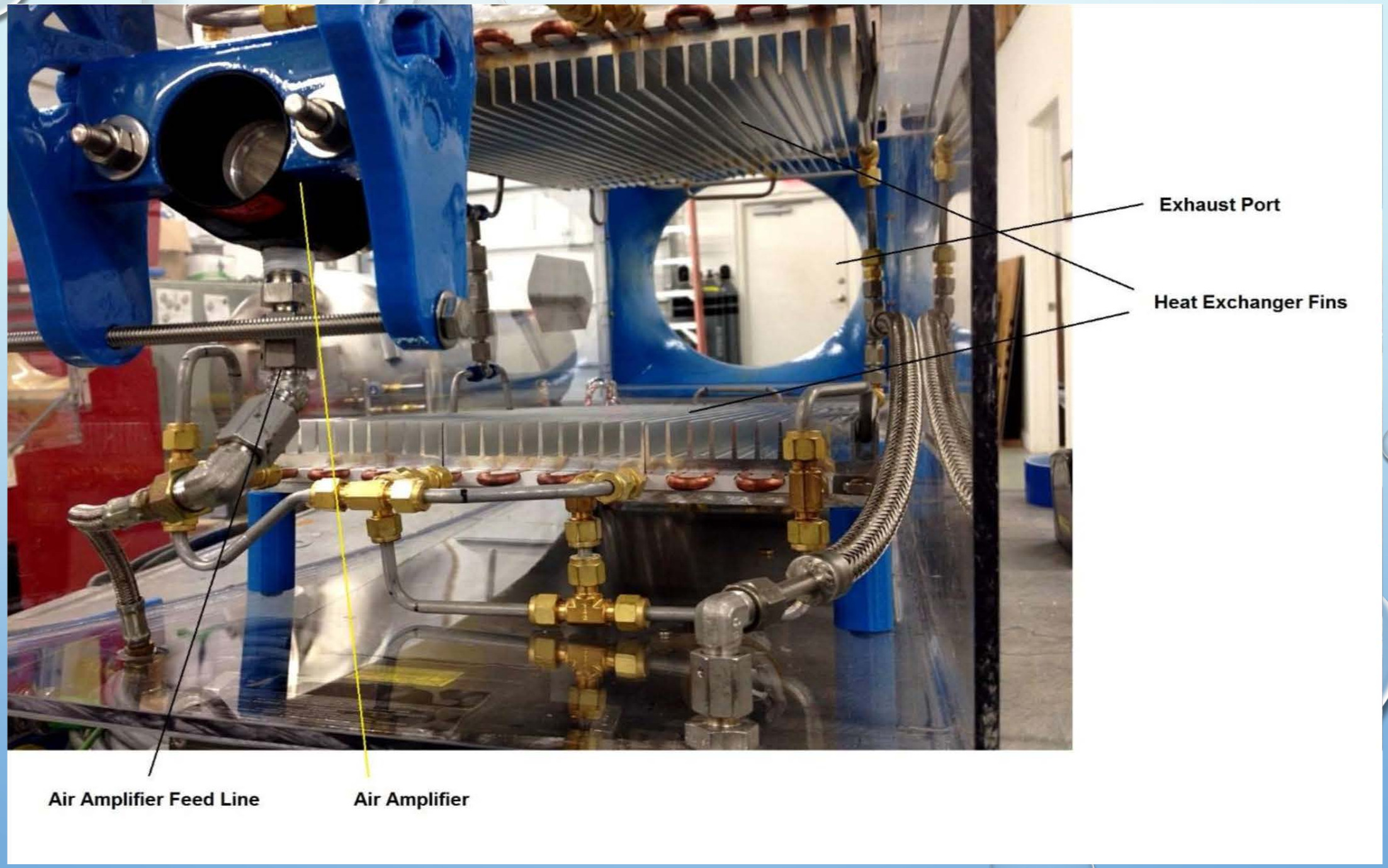
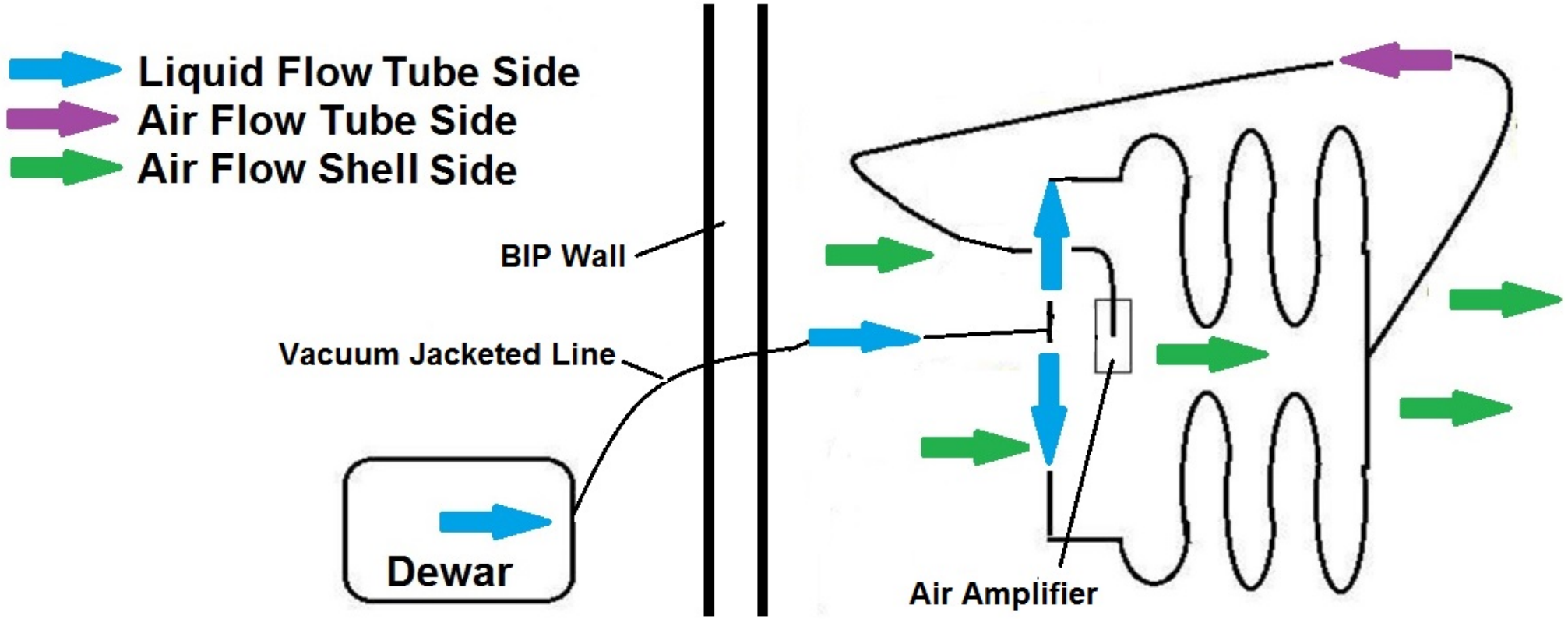
HEAT EXCHANGER BOX


Exhaust Port
Heat Exchanger Fins
Air Amplifier Feed Line
Air Amplifier

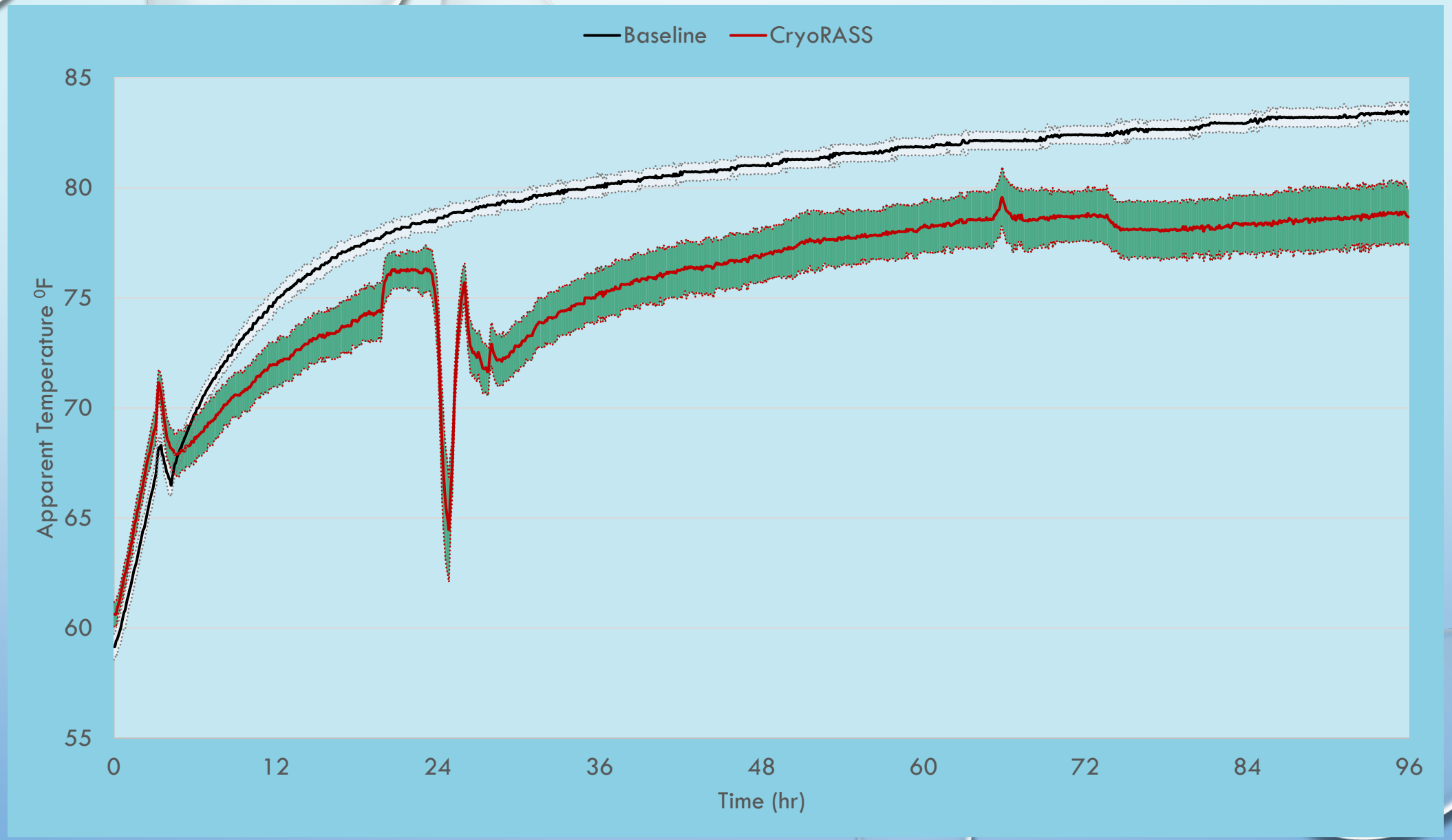
Equipment Description



Flow schematic for heat exchanger

Heat Absorption of Liquid Air Test
November 2014, at Bruceton
23 Man Inflatable

1100	Liters Liquid Air
2119	lbs
88.38	BTU/lb vaporization
187,320	BTU to vaporize 1,100 liters
0.2427	BTU/lb deg F
384	temp change deg F (-318 to 66 deg F)
94.168	BTU/lb to heat
197,529	BTU to heat 1,100 liters
384,848	BTU to vaporize and heat 1,100 liters
23	men
16,822	BTU/man
96	hours
174	BTU/man-hr



Calculated apparent temperature inside 23-man inflatable RA.

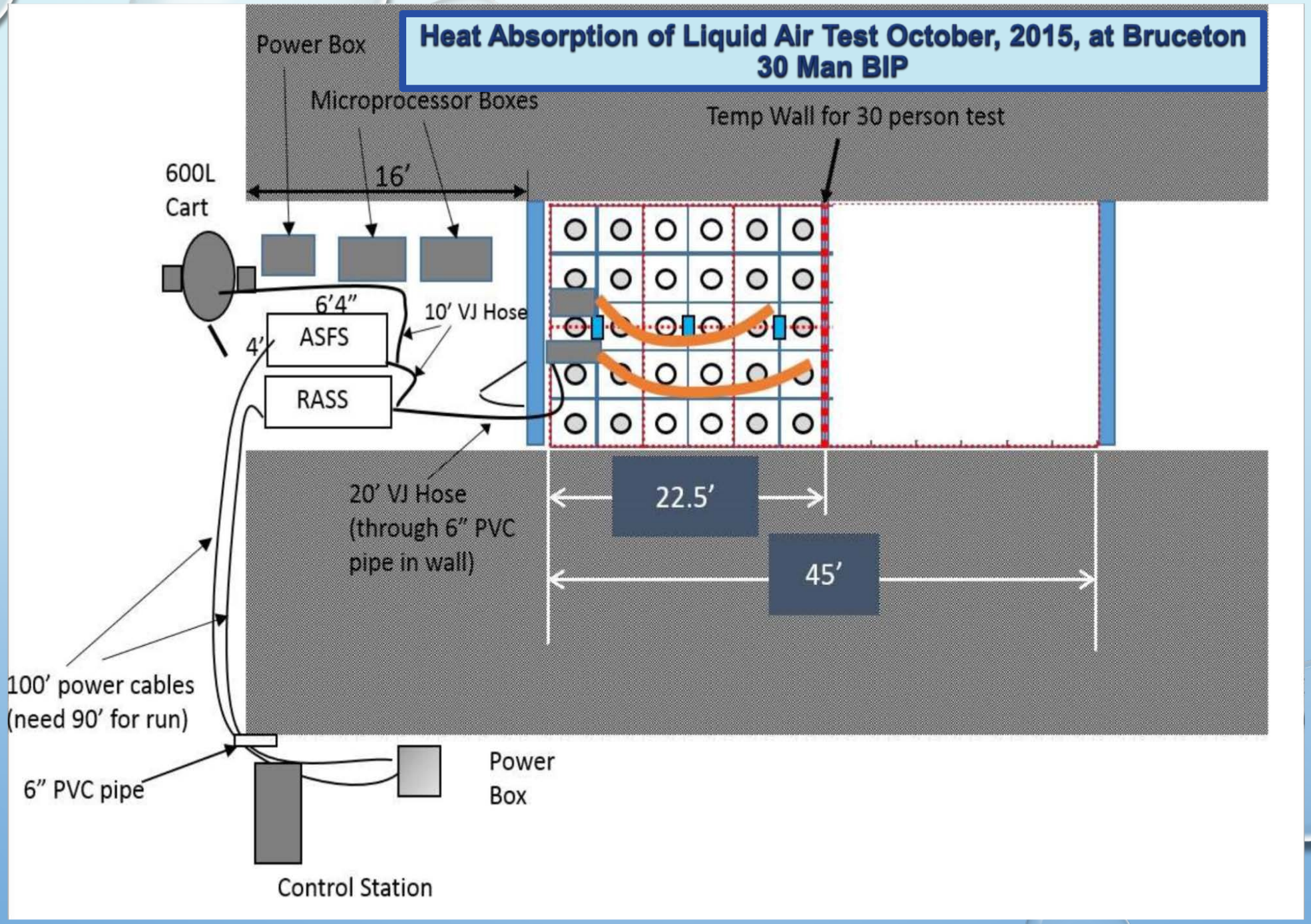
Results

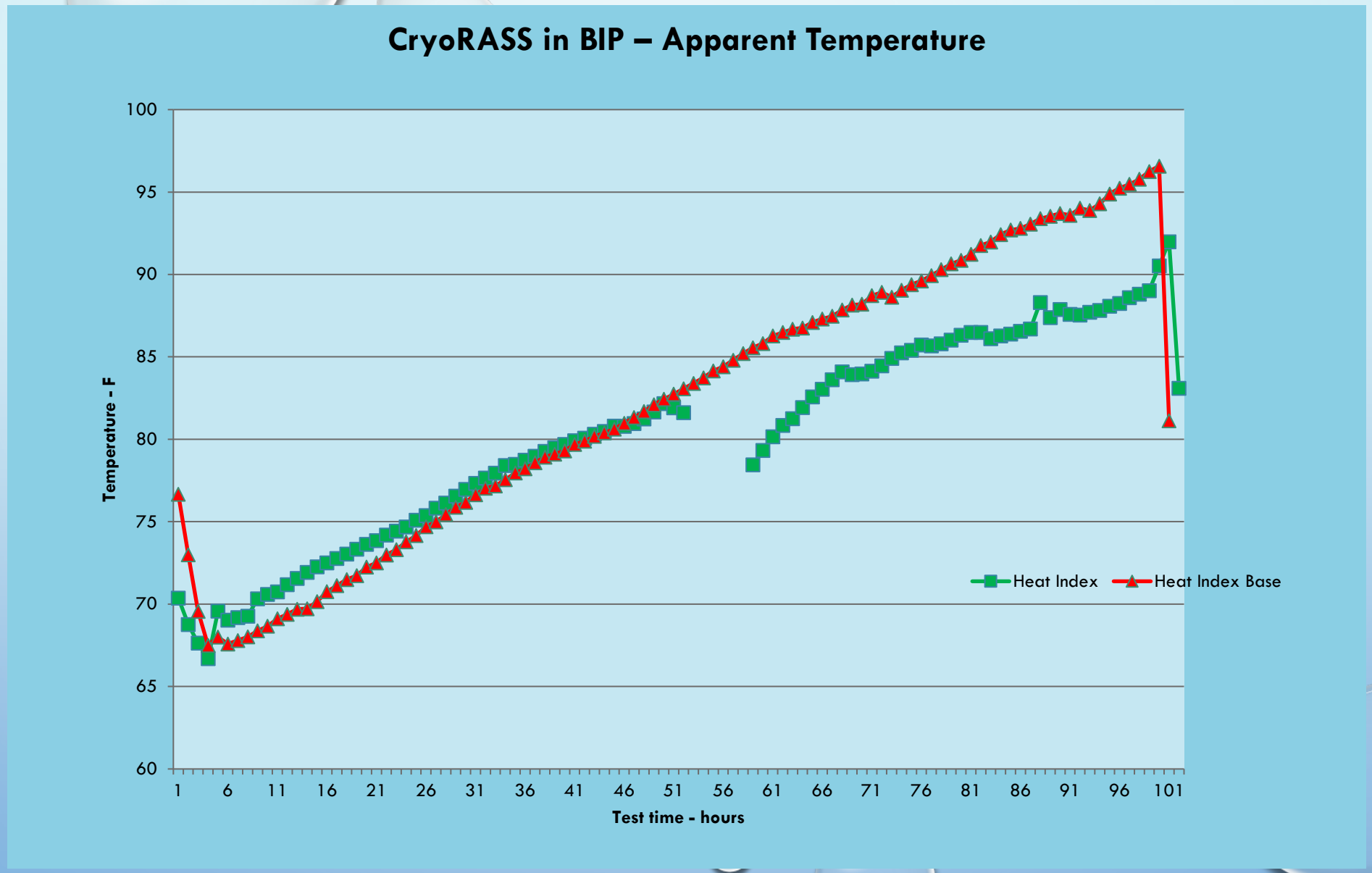
HEAT MITIGATION TEST NOVEMBER 2014, AT BRUCETON.
23 MAN INFLATABLE.
23 “BARREL PERSONS”.
1,100 LITERS LIQUID AIR.
AMBIENT MINE TEMPERATURE 66°F.
CALCULATED LIQUID AIR HEAT ABSORPTION 174 BTU/MAN-HR.
APPARENT TEMPERATURE DID NOT EXCEED 77°F FOR 96 HOURS.

Heat Absorption of Liquid Air Test
October, 2015, at Bruceton
30 Man BIP

1250	Liters Liquid Air
2409	lbs
88.38	BTU/lb vaporization
212,863	BTU to vaporize 1,250 liters
0.2427	BTU/lb deg F
383	temp change deg F (-318 to 65 deg F)
94.168	BTU/lb to heat
223,880	BTU to heat 1,250 liters
436,743	BTU to vaporize and heat 1,250 liters
30	men
14,558	BTU/man
96	hours
152	BTU/man-hr

Heat Absorption of Liquid Air Test October, 2015, at Bruceton 30 Man BIP





Calculated apparent temperature inside 30-man BIP RA.

Results

HEAT MITIGATION TEST OCTOBER, 2015 AT BRUCETON
BIP SHELTER
30 “BARREL PERSONS”
1,250 LITERS LIQUID AIR.
AMBIENT MINE TEMPERATURE 65°F.
CALCULATED LIQUID AIR HEAT ABSORPTION 153 BTU/MAN-HR.
APPARENT TEMPERATURE DID NOT EXCEED 92°F FOR 96 HOURS.

4 Tests in Progress per BAA

1. 34 man inflatable baseline test. No cooling. Turn on all 34 barrel people. When the internal apparent temp reaches 95 deg F, turn off barrel people, one at a time, until the 95 deg F apparent temp can be maintained.

2. 34 man inflatable - Turn on all 34 barrel people and turn on the CryoRASS. Operate for 96 hours to ensure the internal apparent temp remains below 95 deg F

3. 34 man inflatable - Heat the mine ambient to 75 deg F and then perform the same test as test 2 above.

4. 34 man BIP – Heat the BIP area of the mine to 75 deg F and then perform the same test as test 2 above.

Heat Absorption of Liquid Air Tests in Progress per BAA 34 Man

1750	Liters Liquid Air
3372	lbs
88.38	BTU/lb vaporization
298,009	BTU to vaporize 1,750 liters
0.2427	BTU/lb deg F
383	temp change deg F (-318 to 65 deg F)
94.168	BTU/lb to heat
313,432	BTU to heat 1,750 liters
611,440	BTU to vaporize and heat 1,750 liters
34	men
17,984	BTU/man
96	hours
187	BTU/man-hr

NASA has been using Liquid Air for breathing For over 40 years

Thank you,
and have a great day!